COMPARISON OF THE RELATIONS OF SIX FACTORS OF RAW-COTTON QUALITY TO SKEIN STRENGTH OF CARDED YARNS FOR EIGHT CROP YEARS, 1945-52

By

Robert W. Webb, Cotton Technologist

UNITED STATES DEPARTMENT OF AGRICULTURE
U.S. Agricultural Marketing Service, Cotton Division

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SUMMARY AND CONCLUSIONS

The relationship between fiber properties of various kinds of cotton and the strength of the yarns made from them is the subject of continuing studies by the U. S. Department of Agriculture. The information derived from these studies is helpful to the cotton trade and textile industry in choosing those cottons best suited to the manufacture of specific products. Seventeen publications have been issued reporting on the findings in earlier work of this nature.

This report summarizes and compares correlation results that were obtained with skein strength of 22s carded yarn and with count-strength product of all yarn sizes spun from each cotton, representing 10 series of cottons and identified with 8 consecutive crop years, 1945-52.

Twenty multiple correlation analyses are included in this study, representing a total of 2,298 American upland cottons and 7,007 lots of yarn, ranging in size from 14s to 60s.

Six elements of raw-cotton quality were used as independent variables in the analyses, namely, grade index, upper half mean length, length uniformity ratio, fiber fineness (weight per inch), fiber strength, and percentage of mature fibers (standard method).

For the 8 crop years, the coefficient of multiple correlation ($\bar{R}$) with strength of 22s yarn ranged from 0.805 to 0.960, a difference of 0.155 in $\bar{R}$ values. The amounts of variance in strength of 22s yarn ($\bar{R}^2$ x 100) explained by the cotton-quality factors extended from 65 percent to 92 percent, a range of 27 percent. The relative standard errors of estimate ($\bar{S}$) for strength of 22s yarn varied from ± 3.6 percent to ± 7.6 percent, a difference of ± 4.0 percent.

Corresponding values with count-strength product for the 8 crop years were as follows: ($\bar{R}$) = 0.868 to 0.965, a difference of 0.097; ($\bar{R}^2$ x 100) = 75 percent to 93 percent, a range of 18 percent; and relative ($\bar{S}$) = ± 4.4 percent to ± 8.0 percent, a difference of ± 3.6 percent.

The relative importance of the respective cotton-quality elements to strength of 22s yarn and to count-strength product of all yarn sizes, as determined by beta coefficients obtained from multiple correlation analyses, varied more or less for the 10 series of cottons and 8 crop years. Upper half mean length, fiber strength, and fiber fineness, however, generally proved to be the most important cotton-quality factors to 22s yarn strength and count-strength product. In most cases, grade index, length uniformity ratio, and percentage of mature fibers (standard method) had relatively small or negligible effects on yarn strength and count-strength product.

The direction of the contribution of the respective cotton-quality factors to strength of 22s yarn and count-strength product of all yarn sizes, as determined by the sign identified with each beta coefficient obtained from multiple correlation analyses, generally was consistent for the 10 series of cottons and 8 crop years, and was what would be expected. The signs fluctuated more for percentage of mature fibers than for any other cotton-quality factor considered but this was not surprising because of the comparatively small beta values generally obtained for fiber maturity.

The regression equations, showing the mathematical evaluations of the multiple relationships occurring between the variables included in the respective analyses, varied considerably for an individual size of yarn representing different series of cottons or crop years. They also varied appreciably for different yarn sizes processed from a particular series of cottons or crop year.

Two recommended equations are presented for estimating the skein strength of various sizes of carded yarn over a wide range of yarn sizes by the count-strength-product method, - one including 6 cotton-quality factors and the other, the 3 most important quality factors.

An illustration of the calculations necessary for estimating skein strength of any size of yarn is shown for a count-strength-product equation.

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By Robert W. Webb, cotton technologist,
Cotton Division, Agricultural Marketing Service

INTRODUCTION

From this series of relationship studies on cotton fiber properties, 17 previous reports (19 through 35) 1/ were published. The broad problems and objectives underlying these studies, as well as the benefits expected from the development and application of such information, were discussed in a report issued by the Department of Agriculture in 1947 (18).

Questions arise as to the degree of comparability that occurs in statistical results evaluating the relations and relative importance of the measurable cotton fiber properties to yarn strength and to count-strength product, for sizable series of samples, covering a number of consecutive crop years. That is, do such correlation values and regression equations agree rather closely from crop year to crop year over an extended period, or do they fluctuate widely? More particularly, do the evaluated relations represent the same general level in degree for different crop years, or do they show any trends, or do they vary without orderly sequence?

In an effort to answer those questions, statistical values representing the relation of six elements of raw-cotton quality to skein strength of 22s carded yarn and to count-strength product of all carded yarn sizes spun from the various cottons, as obtained from multiple correlation analyses of data identified with 10 series of cottons and 8 crop years, 1945-52, have been summarized in this report. Tabulations have been made of the findings in a manner to afford direct and easy comparisons. Strength of only one individual yarn size could be used as a dependent variable in this summary because of the fact that 22s was the only yarn size that was common to all cottons and crop years.

SAMPLES, TESTS, AND DATA

The sources of the basic fiber and yarn-strength data used in the analyses covered by this report may be found in publications (4) through (15) and (17). The sources of the statistical values for the 3 crop years of 1945, 1946, and 1947 may be had by reference to reports (27) and (28); the source of the values for the 2 crop years of 1951 and 1952 is report (19). The statistical values for the 3 crop years of 1948, 1949, and 1950 constitute heretofore unpublished data.

1/ Underscored numbers in parentheses refer to Literature Cited p. 21.

The fiber, spinning, and yarn-strength tests on the cottons used in these analyses were made in the laboratories of the Cotton Division, Agricultural Marketing Service, at Clemson, S. C., and at College Station, Tex.

Cottons. All cottons were of the American upland type. Seven of the ten series of cottons were grown commercially in selected cotton improvement groups across the American Cotton Belt, within their general area of growth adaption, in the crop years 1946 through 1952. The cottons were ginned on commercial saw gins serving the respective cotton improvement groups.

Three series of cottons were a part of the experiment station annual variety test series, in the crop years 1945 through 1947. These samples were grown, harvested, and ginned through Federal-State cooperative effort at their various experimental stations and substations.

Sampling. Classing samples weighing 4 to 6 ounces were assembled for the most frequently occurring grade and staple-length groups of each selected cotton improvement area, until 8 to 10 pounds of raw cotton had been accumulated. For the last 5 crop years (1948 through 1952), each variety and location of growth were represented by early-season, mid-season, and late-season samples. For 1947, they represented early-season and mid-season samples and, for 1946, they represented only early-season samples.

The original grade and staple length designations, which served as the basis for selecting and compositing the comparable lots of cotton for test purposes, were those assigned to the individual samples of raw cotton by USDA cotton specialists. Classification of the samples was made in accordance with the Universal Standards for Grade and the official standards for staple length, as described for American upland cotton in the publication entitled "The Classification of Cotton" (3).

As a result of the method used for selecting the samples, not all of the range of grades and staple lengths appearing in each cotton improvement area was represented by the test cottons.

One sample of cotton was collected in customary manner, for each variety grown at each location, in connection with the experiment station annual variety test series. Samples weighing 8 to 10 pounds were taken at or near the peak of production for the respective varieties; thus, they largely represented midseason cotton. The samples were classified, in the usual manner, as to grade and staple length.

Processing. Details as to the processing procedure by which the cottons were converted into yarns may be found in the original reports setting forth the fiber and spinning test results for the respective groups of cotton, (4 through 15, 17). Report (16) describes the service testing of cotton by the Cotton Division of AMS, including not only processing procedures and waste analyses but also fiber, yarn and fabric tests. The processing procedures used with the cottons included in the analyses for the 5 crop years of 1945-46-47 and 1951-52 were further described and pointed up in reports (27), (28), and (19), respectively.

In brief, it may be said that all the cottons used in the various studies covered by this report were processed through the picker and card by the same standard procedure, and with the same settings and speeds. The cottons for the 5 crop years of 1945 through 1949 were processed at one rate of card production which was 9-1/2 pounds per hour; those for the 3 crop years of 1950-51-52 were carded at one of 3 different rates of production, depending upon the length of the individual cotton. Cottons of 15/16 inch and shorter in staple length were carded at 12-1/2 pounds per hour; those from 31/32 inch through 1-1/16 inches, were carded at 9-1/2 pounds per hour; and those from 1-3/32 inches through 1-1/4 inches were carded at 6-1/2 pounds per hour.

The fact that the 3 groups of cottons referred to above were carded at somewhat different rates of production did not influence the statistical values obtained from the correlation analyses to any appreciable degree. As shown in report (33), it was found that different rates of card production, ranging even from 2.0 to 15.5 pounds per hour, did not cause the strength of various sizes of carded yarn to vary with any statistical significance. Likewise, for the combed yarn series of cottons reported in (34), the results showed that the effect of different rates of carding, extending from 2.0 to 12.5 pounds per hour, were without statistical significance on the strength of various sizes of combed yarn.

All yarns from all cottons were processed from long-draft roving by long-draft spinning equipment, represented a warp-type of construction, and possessed a semihard twist. The twist multipliers varied with the upper half mean length of the cottons, the one selected for each cotton being that which gave approximately the maximum yarn strength for an average or typical cotton of the particular classified length. The twist multiplier used in each case, therefore, was not selected to compensate for the influence of other fiber properties involved but represented an empirical selection.

Fiber properties. Six elements of raw-cotton quality were used as independent variables in all the multiple correlation analyses covered in this summary report, as follows:

> Upper half mean length, in inches, as determined by the fibrograph method.
>
> Length uniformity ratio, in percent, as determined by the fibrograph.
>
> Fiber fineness, in micrograms per inch, as evaluated by the array method for the 3 crop years of 1945-47 and by the Micronaire method for the 5 crop years of 1948-52.

Fiber strength, in terms of 1,000 pounds per square inch, as determined by the Pressley tester.

Percentage of mature fibers, as classified and counted on the basis of 2-to-1 lumen to wall ratio, after they had been permitted to swell in an 18-percent sodium hydroxide solution.

Grade of cotton, expressed as an index.

Grade index was used in this study, as explained in the report of this series having to do with the strength of 22s yarn, regular draft (26). The conversion chart for obtaining grade index values of samples of raw cotton, corresponding to various grade designations originally assigned, was shown in previous reports of this series.

The fiber tests relating to the data used in these analyses were those described in the publication entitled "Cotton Testing Service" (16) and covered more in detail by ASTM Standards on Textile Materials (1). Such laboratory data were considered further in the first and third reports of this series of relationship studies (20, 22).

All fiber tests were made under controlled atmospheric conditions with a temperature of 70°F ± 2° and a relative humidity of 65 percent ±2 percent according to ASTM specifications (1).

Yarn size. Yarn size, expressed in terms of the generally used or so-called English yarn numbers for cotton, was included as the seventh independent variable in the multiple correlation analyses, when count-strength product of various yarn sizes was used as the dependent variable.

For the 1945, 1946, and 1947 cottons, either 3 or 4 sizes of yarn were spun from each cotton. Yarn numbers were selected so as to represent the widest range generally practicable to spin with each cotton, as influenced by its staple length, and to include one or two intermediate yarn sizes for every cotton. All the cottons were spun into 22s and 36s yarn. The finest yarn spun from each sample was either 60s, 50s, 44s, or 36s, depending upon the respective staple lengths of the cottons. Data representing all yarn sizes processed from all cottons in the series were used in the analyses with count-strength product.

For the 1948 cottons, 4 sizes of yarn were spun from each sample. All the cottons were spun into 14s, 22s, and 36s yarn. The finest yarn spun from each cotton was either 60s, 50s, or 44s, depending upon the respective staple lengths of the cottons. Data representing all yarn sizes processed from all cottons in the series were used in the analysis with count-strength product.

For the 1949 cottons, all samples were spun into 14s, 22s, 36s, and 50s yarn. Data representing all yarn sizes processed from all cottons in the series were used in the analysis with count-strength product.

For the 1950 cottons, either 3 or 4 sizes of yarn were spun from each cotton. All the cottons were processed into 22s and 36s yarn. The finest yarn spun from each sample was either 50s or 36s, and the coarsest yarn processed from each sample was either 22s or 14s, depending upon the respective staple lengths of the cottons. Data representing all yarn sizes processed from all cottons in the series were used in the analysis with count-strength product.

For the 1951 and 1952 cottons, only two sizes of yarn were spun from each cotton but they were not the same two yarn sizes in all instances. Yarn sizes of 22s and 50s were spun for the 280 longer cottons from the 1951 crop and for the 276 longer cottons from the 1952 crop. Yarn sizes of 14s and 22s, however, were spun from the 39 shortest cottons in the 1951 series and from the 33 shortest cottons in the 1952 series. Strength values of both yarn sizes processed from all cottons in each series were included in the respective analyses with count-strength product.

Yarn strength. Conventional skein-strength tests of all yarns were made, according to the generally adopted procedure described in ASTM Standards on Textile Materials (1) and referred to in Cotton Testing Service (16), and expressed in terms of pounds.

Values for count-strength product were obtained by multiplying the individual yarn strengths by their respective yarn sizes, and expressing the results in terms of count-strength-product units.

All yarn-strength tests were made under the same controlled atmospheric conditions, as specified by ASTM for fiber and yarn testing, namely, a temperature of 70°F. ±2° and a relative humidity of 65 percent ±2 percent.

STATISTICAL ANALYSES

This report covers results obtained from 20 multiple correlation analyses, representing a total of 2,298 cottons and 7,007 lots of yarn, ranging in size from 14s to 60s. The yarn size of 22s, however, was the only one that was spun from all cottons from all crop years.

By using as independent variables the six elements of raw-cotton quality previously referred to, the multiple correlation analyses reported herein were made with strength of 22s yarn and with count-strength product of all yarn sizes spun from each cotton, for 10 series of cottons, identified with 8 crop years, 1945-52.

The same general pattern of statistical analyses was followed in this study as that followed in all the previous studies of this series. For more detailed information with regard to the statistical terms, measures, and techniques applied, see Appendixes and literature citations in the first and third reports (20, 22).

Beta coefficients were used to evaluate the relative net importance of the fiber properties to the two dependent variables instead of partial correlation coefficients, the latter of which were used in the early studies of this series. A correction factor was applied to the respective statistical values obtained from all correlation analyses.

All statistical values reported in this summary were obtained from linear correlation analyses. No curvilinear correlation analyses were made because of the ranges of cotton quality factors considered in the various sets of analyses and because of the fact that previous curvilinear analyses in this series of studies had shown no better results with yarn strength than did those from linear correlation analyses.

COMPARISON OF MULTIPLE CORRELATION VALUES IDENTIFIED WITH EIGHT CROP YEARS, 1945-52

Summarized in table 1 of the Appendix 2/ are the statistical values indicating the degree of relation of six factors of raw-cotton quality (grade index, upper half mean length, length uniformity ratio, fiber fineness, fiber strength, and percentage of mature fibers) to skein strength of 22s carded yarn, as obtained from multiple correlation analyses for the 8 respective crop years. In table 2 are summarized corresponding values for 7 factors, including the same 6 cotton-quality elements and yarn size, correlated with count-strength product of all yarn sizes spun from each cotton.

Also listed in tables 1 and 2 are the average strengths of 22s yarn for the various groups of cottons, the latter of which indicate the relative level of yarn strength for the different series and crop years.

With strength of 22s yarn. Referring to table 1 and figure 1, it will be noted that the smallest coefficient of correlation ($\bar{R}$) obtained was 0.805, as identified with the 1951 samples from the selected cotton improvement groups, and that the largest correlation coefficient was 0.960, as associated with the 1947 experiment station annual variety test series. Thus, for the 10 series of cottons representing the 8 respective crop years of 1945-52, there was a range in $\bar{R}$ values of 0.155 with strength of 22s yarn.

The percentages of variance in strength of 22s yarn ($\bar{R}^2$ x 100) explained by the cotton-quality factors considered varied in line with the above $\bar{R}$ values, as also shown by reference to table 1 and figure 1. The smallest amount was 64.8 percent and the largest, 92.1 percent. A range of 27.3 percent, therefore, occurred in the amount of variance of

2/ All tables are grouped in the Appendix at the end of this report and hereinafter they will be referred to only by table number.

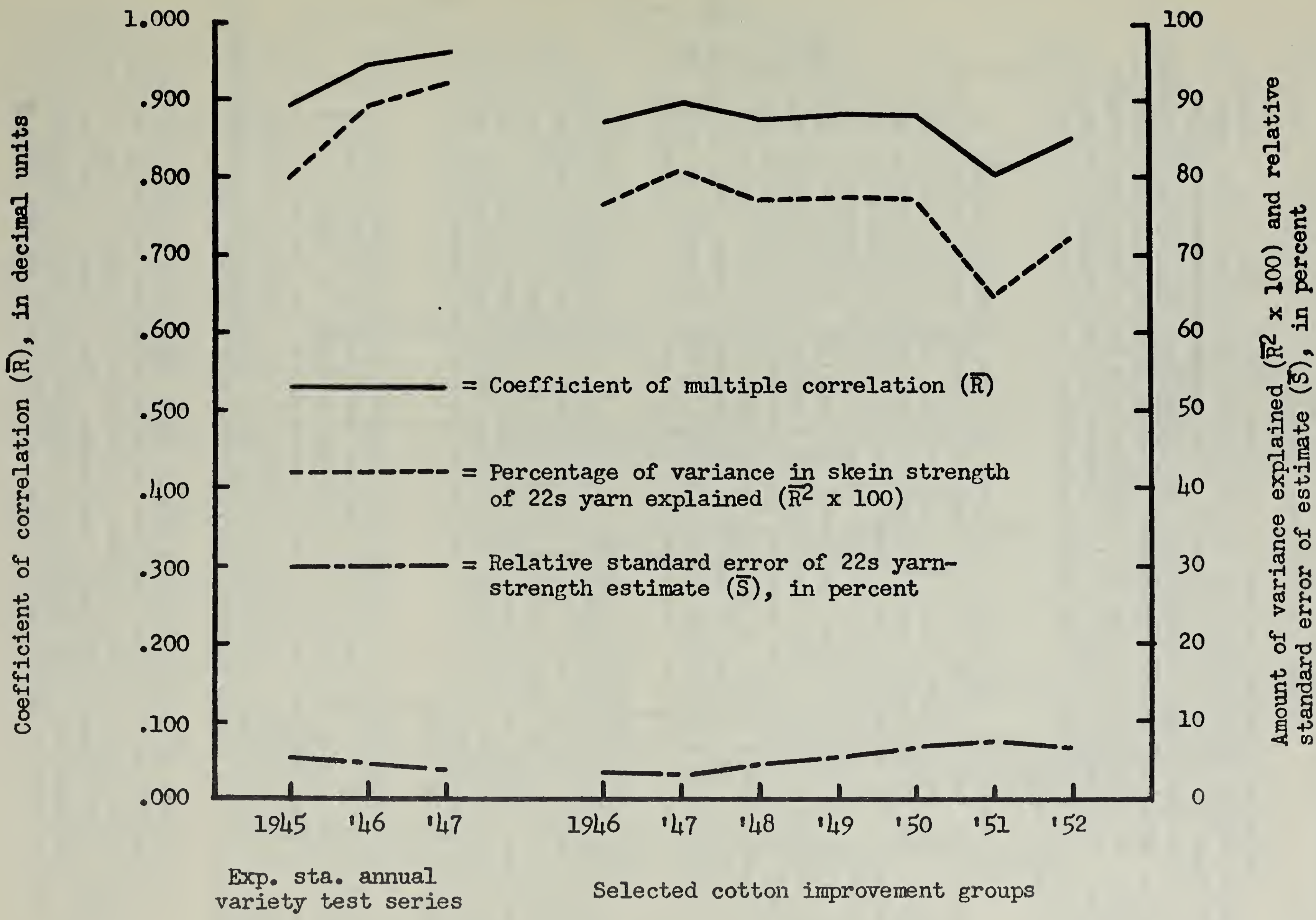

Figure 1.-- Relationship of 6 factors of raw-cotton quality to skein strength of 22s carded yarn, by series and crop years, 1945-52.

22s yarn strength accounted for by the 6 elements of cotton quality used as independent variables in the 10 correlation analyses for the 8 crop years.

Relative standard errors of estimate ($\bar{S}$) for 22s yarn strength likewise varied appreciably for the different series and crop years, as may be seen in table 1 and figure 1. The largest relative standard error of estimate was $\pm$7.6 percent, as identified with the 1951 samples from the selected cotton improvement groups, and the smallest was $\pm$3.6 percent, as furnished by the 1947 samples from the cotton improvement groups. This makes a range of $\pm$4.0 percent in the standard errors of estimate for strength of 22s yarn representing the 10 series of cottons and 8 crop years.

The trend in magnitude of values for the standard errors of estimate for strength of 22s yarn was, in general, the reverse of the trend of the respective $\bar{R}$ and $\bar{R}^2$ x 100 values previously considered; however, the trends were not identical or precisely the same in all instances. For example, the largest $\bar{S}$ value ($\pm$7.6 percent) was obtained with the 1951 samples of the selected cotton improvement groups which group of samples also furnished the smallest $\bar{R}$ and $\bar{R}^2$ x 100 values of the entire series. But, the smallest $\bar{S}$ value ($\pm$3.6 percent) was not obtained with the group of samples that furnished the largest $\bar{R}$ and $\bar{R}^2$ x 100 values. The $\bar{S}$ value of $\pm$3.9 percent associated with the group of cottons giving the largest $\bar{R}$ and $\bar{R}^2$ x 100 values, however, was comparatively small and almost the minimum value obtained, being exceeded by only two other $\bar{S}$ values in the series; namely, $\pm$3.8 percent and $\pm$ 3.6 percent.

With count-strength product. As may be seen by reference to table 2 and figure 2, the smallest coefficient of correlation ($\bar{R}$) with count-strength product was 0.868, as furnished by the 1951 samples from the selected cotton improvement groups and the largest correlation coefficient was 0.965, as obtained with the 1947 experiment station annual variety test series. The range in $\bar{R}$ values with count-strength product, therefore, was 0.097 for the 10 series of cotton representing the 8 respective crop years.

The percentages of variance in count-strength product ($\bar{R}^2$ x 100) explained by the 6 cotton-quality factors and yarn size fluctuated in line with the above $\bar{R}$ values, as also may be noted in table 2 and figure 2. The smallest amount was 75 percent and the largest, 93 percent. A range of 18 percent, therefore, occurred in the amount of variance in count-strength product accounted for by the 7 factors used as independent variables in the 10 correlation analyses for the 8 crop years.

As shown in table 2 and figure 2, with one minor exception, the trend in magnitude of values for the relative standard errors of estimate with count-strength product followed in reverse the trend of the respective $\bar{R}$ and $\bar{R}^2$ x 100 values previously considered. The largest relative standard error of estimate was $\pm$8.0 percent, as obtained with the 1951 samples from the selected cotton improvement groups, and the smallest was $\pm$4.4 percent,

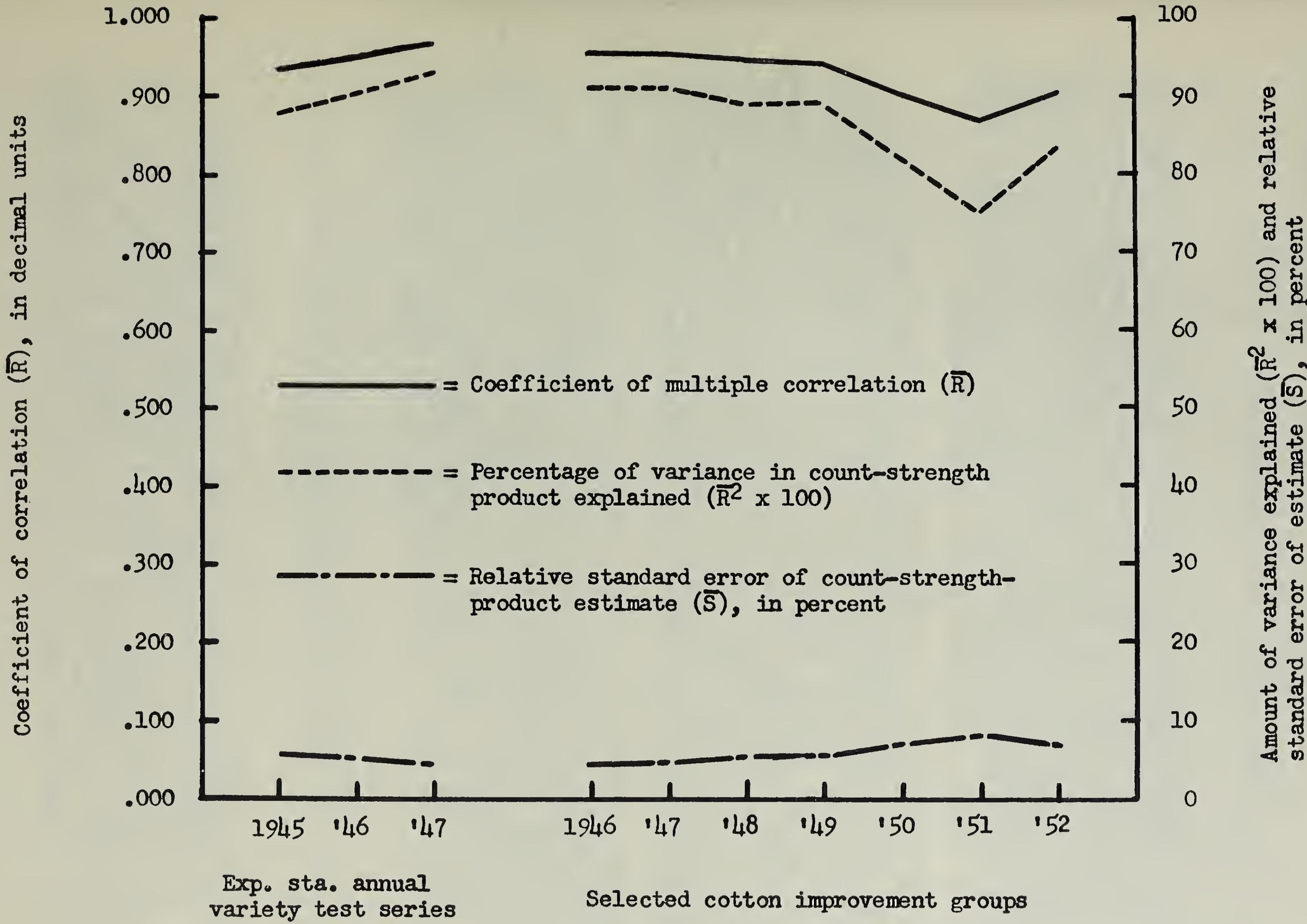

Figure 2.—Relationship of 6 factors of raw-cotton quality and yarn size to count-strength product of all sizes of carded yarn spun (14s to 60s), by series and crop year, 1945-52

as shown by both the 1947 samples from the experiment station annual variety test series and the 1946 samples from the selected cotton improvement groups. Thus, there was a range of ± 3.6 percent in the relative standard errors of estimate for count-strength product representing the 10 series of cottons and 8 crop years.

General considerations. On the basis of $\bar{R}$ and $\bar{R}^2 \times 100$ values, the group of samples from the 1947 experiment station annual variety test series ranked first; that from the 1946 experiment station annual variety test series ranked second; and that from the 1945 experiment station annual variety test rank fourth, being practically equal to the group of samples for the 1947 selected cotton improvement groups which ranked third. That the cottons identified with experiment station annual variety test series gave, in general, larger $\bar{R}$ and $\bar{R}^2 \times 100$ values than did the samples associated with the cotton improvement groups is understandable.

By way of explanation of those disparities, the ranges of fiber properties, of 22s yarn strength, and of count-strength product used in the respective analyses generally were larger in the case of the experiment station annual variety test series than with the selected cotton improvement groups, and the observations were better distributed throughout their ranges. The ranges of those variables were more restricted in the analyses of samples from the selected cotton improvement groups and the observations were more concentrated around their respective mean values, as naturally might be expected because of the fact that the samples from the cotton improvement groups represented so-called average cottons.

Moreover, each lot of cotton from the experiment station annual variety test series represented one location of growth, one date of picking, and a so-called homogeneous sample in a certain sense; that is, one major pattern or combination of fiber properties. Each lot of cotton from the selected cotton improvement groups, on the other hand, represented--in all cases--composite samples of 4 to 6 ounces drawn from 25 to 40 commercial bales of cotton grown over a sizable area within the respective cotton improvement groups. Further, except for one series, the various groups of samples from the cotton improvement groups used in each analysis represented 2 or 3 dates of picking. Therefore, in the case of the samples from the cotton improvement groups, each lot of cotton represented a so-called heterogeneous sample in the sense that it contained more than one major pattern or combination of fiber properties.

It is of interest to note from the results presented in table 1 and figure 1 that, when strength of 22s yarn was used as the dependent variable, the $\bar{R}$ and $\bar{R}^2 \times 100$ values were approximately equal for the 3 series of samples from the selected cotton improvement groups, crop years of 1948, 1949, and 1950. Their respective $\bar{R}$ values were 0.878, .881, and .880; and their corresponding $\bar{R}^2 \times 100$ values were 77.1, 77.5, and 77.4 percent. For count-strength product as the dependent variable, the $\bar{R}$ and $\bar{R}^2 \times 100$ values were essentially identical in the case of the first

two series of samples but such did not hold true for the third group of cottons, as shown by table 2 and figure 2.

It also is of interest to note that, when strength of 22s yarn was used as the dependent variable, the smallest $\bar{R}$ and $\bar{R}^2$ x 100 values were obtained with the 1951 and 1952 samples from the selected cotton improvement groups. With count-strength product, the smallest $\bar{R}$ and $\bar{R}^2$ x 100 values were obtained with the 1951 samples from the cotton improvement groups and the next smallest with corresponding samples from 1950 and 1952. The crop years of 1951 and 1952, according to the record, were relatively dry for much of the time over many areas throughout the American Cotton Belt. It may be, therefore, that the factor of rainfall or soil moisture influenced various combinations of the fiber properties enough to cause the relatively small $\bar{R}$ and $\bar{R}^2$ x 100 values obtained for those two crop years.

As shown by a comparison of the results reported in tables 1 and 2, all the $\bar{R}$, $\bar{R}^2$ x 100, and relative $\bar{S}$ values were larger when count-strength product was used as the dependent variable than when strength of 22s yarn was so used. For the 8 crop years and 10 series of analyses, the $\bar{R}$ values with count-strength product averaged 0.046 larger than those with strength of 22s yarn, the individual differences ranging from +0.004 to +0.080; the $\bar{R}^2$ x 100 values averaged 8.3 percent larger, the individual differences ranging from +0.1 percent to +14.7 percent; and the relative $\bar{S}$ values averaged +0.5 percent larger, the individual differences ranging from +0.2 percent to +0.9 percent. Those differences in statistical values are understandable and explainable by virtue of the fact that 6 cotton-quality elements were used as the independent variables in the case of the analyses with strength of 22s yarn, whereas 7 independent variables--including the same 6 cotton-quality factors and yarn size--were employed as independent variables in the analyses with count-strength product of all yarn sizes spun from each cotton. Moreover, as a consequence, the number of observations used in each analysis with count-strength product was 2, 3, or 4 times the number used in the corresponding analysis with strength of 22s yarn.

COMPARISON OF BETA COEFFICIENTS IDENTIFIED WITH EIGHT CROP YEARS, 1945-52

Summarized in table 3 are the values of beta coefficients for the 6 elements of raw-cotton quality previously referred to, as obtained from multiple correlation analyses with skein strength of 22s carded yarn, representing 10 series of cottons and 8 crop years. Those values indicate the relative net importance of the respective factors to 22s yarn strength for each of the series of cottons and crop years.

Similar values of beta coefficients are shown in table 4 for the relative net importance of the same 6 cotton-quality factors and yarn size toward count-strength product of all yarn sizes spun from each cotton (2, 3, or 4), identified with each of the 10 series of cottons and 8 crop years.

Relative importance of 6 factors with strength of 22s yarn. As shown by table 5, of the elements of cotton quality considered in the 10 series of cottons, fiber strength ranked first in importance to skein strength of 22s yarn 5 times; second, 3 times; and third, twice. All beta values for fiber strength in relation to 22s yarn strength were statistically significant.

Fiber fineness (weight per inch) ranked second in importance to skein strength of 22s yarn strength 3 times; third, 4 times; fourth, twice; and sixth, once. Eight of the 10 beta values for fiber fineness in relation to 22s yarn strength were statistically significant.

Upper half mean length ranked first in importance to skein strength of 22s yarn 5 times; second, three times; and third, twice. All beta values for upper half mean length in relation to 22s yarn strength were statistically significant.

Grade index ranked second in importance to skein strength of 22s yarn once; third, once; fourth, 4 times; fifth, 3 times; and sixth, once. Seven of the 10 beta values for grade index in relation to 22s yarn strength were statistically significant.

Length uniformity ratio ranked fourth in importance to skein strength of 22s yarn 3 times; fifth, 6 times; and sixth, once. Six of the 10 beta values for length uniformity ratio in relation to 22s yarn strength proved to be statistically significant.

Percentage of mature fibers (standard method) ranked third in importance to skein strength of 22s yarn once; fourth, once; fifth, once; and sixth, 7 times. Only one of the 10 beta values for percentage of mature fibers in relation to 22s yarn strength was found to be statistically significant.

Relative importance of 7 factors with count-strength product. As shown by table 6, of the factors considered for the 10 series of cottons, yarn size ranked first in importance to count-strength product in every instance. All beta values for yarn size in relation to count-strength product were statistically significant.

Fiber strength ranked second in importance to count-strength product 3 times; third, 4 times; fourth, twice; and fifth once. All beta values for fiber strength in relation to count-strength product were statistically significant.

Upper half mean length ranked second in importance to count strength product 5 times; third, 3 times; and fourth, twice. All beta values for upper half mean length in relation to count-strength product were statistically significant.

Fiber fineness (weight per inch) ranked second in importance to count-strength product twice; third, twice; fourth, 5 times; and seventh, once. Nine of the 10 beta values for fiber fineness in relation to count-strength product were statistically significant.

Length uniformity ratio ranked fifth in importance to count-strength product 4 times; sixth, 3 times; and seventh, 3 times. Seven of the 10 beta values for length uniformity ratio in relation to count-strength product were statistically significant.

Grade index ranked third in importance to count-strength product once; fifth, 3 times; sixth, 5 times; and seventh, once. Eight of the ten beta values for grade index in relation to count-strength product were statistically significant.

Percentage of mature fibers (standard method) ranked fourth in importance to count-strength product once; fifth, twice; sixth, twice; and seventh, 5 times. Six of the 10 beta values for percentage of mature fibers in relation to count-strength product were statistically significant.

It is of interest to note that, with count-strength product representing all yarn sizes spun (14s, 22s, 36s, and 50s), six of the 10 beta coefficients for percentage of mature fibers were statistically significant, whereas only one of the 10 beta coefficients for percentage of mature fibers was statistically significant with strength of 22s yarn. On the surface, the former might be assumed to be the result, in part, of the fact that two finer sizes of yarn also were included collectively in the analysis with count-strength product, namely, 36s and 50s. Unpublished beta values obtained with strength of 36s yarn and 50s yarn for each of the 3 crop years, 1948-50, however, do not support that assumption.

COMPARISON OF SIGNS BEFORE BETA COEFFICIENTS IDENTIFIED WITH EIGHT CROP YEARS, 1945-52

The plus or minus sign shown before the value of each beta coefficient listed in tables 3 and 4 indicates the direction of the contribution of each element of raw-cotton quality considered toward skein strength of 22s carded yarn and count-strength product of all yarn sizes, respectively.

With strength of 22s yarn. Summarized in table 7 are the signs attached to the beta values for the respective cotton-quality factors, representing the 10 series of cottons and 8 crop years, toward 22s yarn strength.

Fiber strength showed positive beta values in all 10 cases, indicating that the stronger the fibers the stronger was the 22s yarn.

Fiber fineness (weight per inch) was accompanied by negative beta values in 9 cases and by one positive beta value (crop of 1952). The latter beta value, however, was statistically insignificant, which eliminates any importance being attached to the exceptional sign. The preponderance of negative signs means that the smaller the fiber weight per inch or the finer the fiber, the stronger was the 22s yarn.

Upper half mean length showed positive beta values in all 10 cases, indicating that the longer the fibers the stronger was the 22s yarn.

Grade index exhibited positive beta values in all 10 cases, meaning the larger the grade index the stronger was the 22s yarn.

Length uniformity ratio was accompanied by positive signs in all cases but one, and the beta value of this exception was statistically insignificant. No particular importance, therefore, should be attached to the negative sign in this case. The preponderance of positive signs indicates that the larger the length uniformity ratio the stronger was the 22s yarn.

The sign of the beta values were more variable in the case of percentage of mature fibers toward skein strength of 22s yarn than for any of the other cotton-quality elements included in the analyses. Seven of the beta values were positive, indicating that the larger the percentage of mature fibers the stronger was the 22s yarn. Three of the beta values, however, were negative which is taken to indicate that the smaller the percentage of mature fibers the stronger was the yarn. As all beta values for percentage of mature fibers with strength of 22s yarn were statistically insignificant except the one for the crop of 1952, no importance is attached to the fluctuating direction found for the evaluated contribution of percentage of mature fibers toward 22s yarn strength.

With count-strength product of all yarn sizes. Summarized in table 8 are the signs attached to the beta values for the respective cotton-quality elements and yarn size, representing the 10 series of cottons and 8 crop years, toward count-strength product of all yarn sizes spun.

Yarn size showed negative beta values in all 10 cases, indicating that the finer or smaller the yarn the lower was the count-strength product.

Fiber strength was accompanied by positive beta values in all 10 cases, indicating that the stronger the fibers the larger was the count-strength product.

Upper half mean length exhibited positive beta values in all cases, indicating that the longer the fibers the larger was the count-strength product.

Fiber fineness (weight per inch) showed negative beta values in 8 cases and positive beta values in 2 instances. One of the latter beta values was statistically insignificant, so no importance is attached to its unexpected sign. The other positive beta value, crop of 1949, that was statistically significant for fiber fineness in relation to count-strength product cannot be explained at present. All transcription and calculations were carefully rechecked without finding any error or explanation of fiber fineness (weight per inch) toward count-strength product in that instance. All that can be said at present, therefore, is that the exceptional sign did occur. The preponderance of negative signs with the beta values for fiber weight per inch, however, indicates that generally the smaller the fiber weight per inch, or the finer the fiber, the larger was the count-strength product.

Length uniformity ratio showed a positive relation to count-strength product for 8 series of cottons and a negative one in 2 cases. The beta value with one of the latter, however, was statistically insignificant. In general, therefore, the larger the uniformity ratio the larger was the count-strength product.

Grade index exhibited a positive relation toward count-strength product in all 10 instances, meaning the larger the grade index the larger was the count-strength product.

Percentage of mature fibers (standard method) revealed a positive relation toward count-strength product with 8 groups of cotton and a negative relation with 2 series. Of the beta values possessing a positive sign, four were statistically significant and four were insignificant. The two beta values accompanied by a negative sign were statistically significant. While percentage of mature fibers is not a good measure of cotton fiber maturity, as discussed in publications (19) and (30), the findings presented in this summary indicate that, in general, the larger the percentage of mature fibers the larger was the count-strength product.

COMPARISON OF MULTIPLE REGRESSION EQUATIONS IDENTIFIED WITH EIGHT CROP YEARS, 1945-52

A summary of all the multiple regression equations obtained in this study, showing the relations of 6 elements of raw-cotton quality to strength of various sizes of yarn, as well as that for the same 6 cotton-quality factors and yarn size to count-strength product of all yarn sizes spun, is presented in table 9. The equations are listed

by crop year and yarn size in order to afford easy comparison, together with their respective standard errors of estimate expressed on both an absolute and relative basis.

All 22 equations listed are not published as a basis for estimating yarn strength or count-strength product from a knowledge of values representing the respective factors included. Rather, the equations are presented merely to reveal the mathematical evaluation of the multiple relationships existing between the measures of the various factors used in the respective analyses.

The values that go to make up a particular equation are relative throughout and comparative within themselves. The values for the respective regression coefficients, however, are not strictly comparable from equation to equation because of the fact that the level of the regression values in each equation is identified with the value shown for the constant (A) of each equation, and that the (A) values differ appreciably in the various equations.

Pertinent information bearing on the multiple relationships occurring between the variables considered in the respective analyses, other than that already presented in the various tables of statistical values and discussed in previous chapters of this report, may be obtained from the regression equations. This is possible because of the fact that the respective regression coefficients in such equations serve to indicate directly the amount of change in a particular dependent variable caused, on the average, by one unit increase in each independent variable. The sign attached to a regression coefficient signifies whether a unit increase in the value of an independent variable produces an increase or decrease in the scale of values for the dependent variable.

In examining and comparing the values of the regression coefficients listed in table 9, it should be remembered that different units of measurement necessarily had to be used for the various independent variables included in the statistical analyses, as shown in the following tabulation:

Independent variables	Unit of measurement
Grade of cotton	1 index unit
Upper half mean length	1 inch
Length uniformity ratio	1 index unit
Fiber fineness	1 microgram per inch
Percentage of mature fibers	1 percent
Fiber strength	1,000 lb. per sq. in.
Yarn size	1 yarn number

As shown before, the unit of measurement for upper half mean length is 1 inch. Therefore, if the effect of upper half mean length on a dependent variable is desired in terms of the more conventional

units of 1/32-inch, as generally used in the cotton trade and textile industry, the regression coefficients shown in the equations for the length factor should be divided by 32. No further calculations or adjustment, however, are needed in connection with any of the other regression coefficients.

From an examination of the equations shown in table 9, it is evident that they vary appreciably for different yarn sizes associated with a particular series of cottons or crop year, and that they also vary considerably for an individual size of yarn processed from different groups of cottons or crop years. Such findings are those that naturally would be expected.

The signs attached to the constant (A) values were negative in all 22 equations and those for the regression coefficients of a particular fiber property were consistent throughout all equations except as follows: once with grade index, once with length uniformity ratio, 3 times with fiber fineness, and 7 times with percentage of mature fibers. No particular significance is attached to the relatively large number of inconsistent signs occurring with the regression coefficients for percentage of mature fibers, as this fiber property was found to contribute so little to yarn strength in most cases. Explanation for the inconsistent signs with the several other regression coefficients, however, is not known at present.

The available equations best adapted for estimating yarn strength are listed and discussed in the following chapter entitled "Equations Recommended for Estimating Skein Strength of Various Sizes of Carded Yarn."

Calculations required for estimating yarn strength by a count-strength-product equation are shown in a later chapter entitled "Illustration of Calculations Necessary for Estimating Yarn Strength."

EQUATIONS RECOMMENDED FOR ESTIMATING SKEIN STRENGTH OF VARIOUS SIZES OF CARDED YARN

All equations for estimating skein strength of cotton yarns on the basis of certain elements of raw-cotton quality, as covered in this report, refer to carded warp yarns, processed on long draft equipment, and possessing a semi-hard twist. No analyses have been made with single-strand strength of yarns and no analyses have been included for yarns processed on regular-draft equipment.

The yarn-strength estimates obtained for other cottons by use of the equations and procedures recommended in this report should be relatively accurate, as expressed in terms of the fiber tests, textile processing, and yarn structure used in the laboratories of the Cotton Division, Agricultural Marketing Service. For the same accuracy of

sampling, fiber measurements, and yarn tests, however, the level of yarn-strength estimates derived by use of the equations here reported may be expected to vary somewhat from the actual yarn-strength values obtained by others from other cottons, as influenced by the textile-processing organization used and by the amount of twist in the yarns.

After several trial determinations, however, if one finds that the yarn-strength estimates obtained by use of any of the equations presented in this report consistently differ from his actual yarn-strength values, he can adjust his future estimates or predictions to his level of fiber tests, textile processing, yarn structure, and yarn twist by increasing or decreasing them by whatever percentage he finds to be necessary. Obviously, it would be impractical to develop such equations for estimating yarn strength that would represent each and every one of the many processing organizations and yarn structures available in the textile industry today.

But, by following the procedure of adjustment of yarn-strength estimates suggested above, more flexibility is given to the available equations than otherwise would be possible, and the individual needs of different cotton spinners are better served in maintaining quality control and meeting specifications of manufactured products. Thus, the limited number of equations here reported can be so used in a manner by supplemental procedure as to serve satisfactorily most practical problems and purposes connected with skein strength of carded cotton yarn, and more particularly carded warp yarn.

Estimation of yarn-strength by count-strength product equations. The best over-all equation for estimating directly the skein strength of any size of carded singles yarn from 10s to 60s on the basis of 6 elements of raw-cotton quality, as developed to date from this series of analyses, is the count-strength product regression equation which represents 828 selected cottons covering a wide range of quality and 2,484 lots of yarn extending from 22s to 50s, crop years of 1945-47. That equation is listed as follows:

$$X'_{91} = -601.01 - 17.969X_{41} + .618X_{88} + 1378.292X_{17} + 14.833X_{19} - 247.840X_4 + 4.624X_{35} + 19.852X_{33} \qquad (\bar{R} = 0.936;\ \bar{R}^2 = 0.875;\ \bar{S} = \pm 126 \text{ csp units})$$

Where X'_{91} = estimated count-strength product, in csp units

X_{41} = size of yarn, as yarn number

X_{88} = grade of cotton, as an index

X_{17} = upper half mean length, in inches

X_{19} = uniformity ratio, as an index

X_4 = fiber weight per inch, in micrograms

X_{35} = percentage of mature fibers

X_{33} = fiber strength (Pressley), in 1,000 lb. per sq. in.

By using the 3 most important fiber properties, as revealed by the beta coefficients derived from the analyses of the data from which the above equation was derived, the following equation was developed:

$$X'_{91} = +299.02-18.046X_{41}+1632.226X_{17}-163.199X_{4}+20.531X_{33}$$

$$(\bar{R} = 0.927;\ \bar{R}^2 = 0.859;\ \bar{S} = \pm 135 \text{ csp units})$$

As may be noted from the symbols previously defined, the four independent variables used in the above equation are yarn size, upper half mean length, fiber fineness (weight per inch), and fiber strength. The three variables omitted in this instance are percentage of mature fibers, uniformity ratio, and grade.

By comparing the statistical values indentified with the two equations, it is evident that the four independent variable equation should give practically as reliable estimates as the seven independent variable equation. This is a matter of importance from the standpoint of required laboratory work and statistical calculations, and results more particularly in a saving of the time and expense necessary for making the fiber maturity test.

Comparative precision of yarn-strength estimates identified with count-strength-product and individual yarn-size equations. As discussed in report (28), one of the principal objectives of that study was to develop an all-purpose equation rather than equations for specific sizes of yarn, such as 22s and 50s. With equations for individual yarn sizes, use of a conversion formula is required in order to obtain estimates of strength of sizes of yarn other than that for which the equation was developed. The conversion formula heretofore used in these studies was that reported by Campbell (2).

The comparative estimates and differences shown in report (28) indicate that the count-strength-product equation gives practically the same precision of estimate as do the equations for specific yarn sizes used either separately or in conjunction with the conversion formula. A slight tendency, however, is noticed for the latter method to yield yarn-strength estimates slightly more accurate. But, on an average, the standard error is only ±0.23 pound more for the count-strength-product equation than for the equations developed for 22s and 50s yarn, used either separately or in conjunction with the conversion formula. For 14s yarn, the standard error with the count-strength-product equation is ±0.40 pound more; for 22s, ±0.07 pound more; for 36s, ±0.10 pound more; for 44s, ±0.54 pound more; for 50s, ±0.26 pound more; and for 60s, there is no difference. Such small differences, for all practical purposes, may be disregarded.

Thus, on the basis of the comparative statistical values, it is apparent that there is a very close agreement in the results by the two methods of calculating yarn-strength estimates. However, by the count-strength-product method, only one equation is necessary for any size of yarn over a wide range whereas, by the strength equations for specific sizes of yarn two or more equations are necessary, as well as a conversion formula. For broad and practical purposes, therefore,

a count-strength-product equation possesses distinct advantages over several individual yarn-size equations for estimating the strength of various sizes of yarn.

Calculations required for estimating yarn strength by a count-strength-product equation are shown in the following chapter entitled "Illustration of Calculations Necessary for Estimating Yarn Strength."

ILLUSTRATION OF CALCULATIONS NECESSARY FOR ESTIMATING YARN STRENGTH

Yarn strength estimated by count-strength-product equation. The method of estimating yarn strength by the over-all count-strength-product equation developed from 2,484 observations representing 828 cottons, crop years 1945-47, is described below. The fiber data used in this example represent one cotton in that series.

Calculations are illustrated in this instance for estimating the strength of three sizes of yarn, namely, 22s, 36s, and 60s yarn. Estimates of strength for any size of yarn, however, may be obtained by the same procedure, except that care must be exercised to multiply the factor of -17.969 in the equation by the particular size of yarn in question.

Following is the equation:

$$X'_{91} = -601.01-17.969X_{41}+.618X_{88}+1378.292X_{17}+14.833X_{19}-247.840X_{4}$$
$$+4.624X_{35}+19.852X_{33}$$

Substitutions are made in the equation, as follows:

X_{41} = size of yarn (22s, 36s, 60s)

X_{88} = 100, grade index corresponding to Middling

X_{17} = 1.05, upper half mean length, in inches

X_{19} = 77, uniformity ratio, as an index

X_{4} = 4.3, fineness of fiber, in micrograms per inch

X_{35} = 81 percentage of mature fibers

X_{33} = 69, tensile strength of the fibers, in terms of 1,000 lb. per sq. in.

Factors--	Estimated strength of-- 22s	36s	60s
Constant = ...	- 601.01	- 601.01	- 601.01
- 17.969 x 22 = ...	- 395.32	--	--
- 17.969 x 36 = ...	--	- 646.88	--
- 17.969 x 60 = ...	--	--	-1078.14
+ .618 x 100 = ...	+ 61.80	+ 61.80	+ 61.80
+1378.292 x 1.05 = ...	+1447.21	+1447.21	+1447.21
+14.833 x 77 = ...	+1142.14	+1142.14	+1142.14
-247.840 x 4.3 = ...	-1065.71	-1065.71	-1065.71
+4.624 x 81 = ...	+ 374.54	+ 374.54	+ 374.54
+19.852 x 69 = ...	+1369.79	+1369.79	+1369.79
Total	+2333.44	+2081.88	+1650.62
$\frac{2333.44}{22}$ = ...	106.1	--	--
$\frac{2081.88}{36}$ = ...	--	57.8	--
$\frac{1650.62}{60}$ = ...	--	--	27.5
Actual yarn strength obtained	105	56	27
Difference between estimated and actual yarn strength, in pounds	+ 1.1	+ 1.8	+0.5

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APPENDIX

Table 1.—Comparison of statistical values obtained from multiple correlation analyses for 6 elements of raw-cotton quality with skein strength of 22s carded yarn, processed on long-draft equipment and possessing a semi-hard twist, for 10 series of cottons and 8 crop years, 1945-52 1/

Crop Year	Groups of cotton according to—	Time of picking	Lots of— Cotton	Lots of— 22s yarn	Average strength of 22s yarn	Values of— $\bar{R}$	Values of— $\bar{R}^2 \times 100$	Values of— $\bar{S}$
			Number	Number	Pounds			Percent 2/
1945	Experiment station annual variety test series	Mid-season	210	210	111	0.894 ± 0.014	79.9	± 5.2
1946	Experiment station annual variety test series	Mid-season	257	257	114	.943 ± .007	88.9	± 4.4
1946	Selected cotton improvement groups	Mid-season	78	78	110	.874 ± .027	76.3	± 3.8
1947	Experiment station annual variety test series	Mid-season	117	117	115	.960 ± .007	92.1	± 3.9
1947	Selected cotton improvement groups	Early and mid-season	166	166	110	.899 ± .015	80.8	± 3.6
1948	Selected cotton improvement groups	Early, mid-season, and late	277	277	112	.878 ± .014	77.1	± 4.4
1949	Selected cotton improvement groups	Early, mid-season, and late	260	260	113	.881 ± .014	77.5	± 5.3
1950	Selected cotton improvement groups	Early, mid-season, and late	305	305	106	.880 ± .013	77.4	± 6.7
1951	Selected cotton improvement groups	Early, mid-season, and late	319	319	114	.805 ± .020	64.8	± 7.6
1952	Selected cotton improvement groups	Early, mid-season, and late	309	309	111	.849 ± .016	72.1	± 6.3

1/ The 6 cotton-quality elements used as independent variables in each of these correlation analyses were as follows: Grade index, upper half mean length, length uniformity ratio, fiber fineness (weight per inch), fiber strength, and percentage of mature fibers (standard method). Fiber fineness was evaluated by the array method for the 3 crop years of 1945-47 and by the Micronaire method for the 5 crop years of 1948-52.

2/ Absolute value of standard error of estimate ($\bar{S}$) divided by the respective mean value of the dependent variable, multiplied by 100.

Table 2.--Comparison of statistical values obtained from multiple correlation analyses for 6 elements of raw-cotton quality and yarn size with count-strength product, representing a practical range of yarn sizes for each cotton, processed on long-draft equipment and possessing a semi-hard twist, for 10 series of cottons and 8 crop years, 1945-52 1/

Crop year	Groups of cotton according to--	Time of picking	Lots of-- Cotton	Lots of-- Yarn 2/	Average strength of 22s yarn	Values of-- $\bar{R}$	Values of-- $\bar{R}^2 \times 100$	Values of-- $\bar{S}$
			Number	Number	Pounds			Percent 3/
1945	Experiment station annual variety test series	Mid-season	210	630	111	0.937 ± 0.005	88	± 5.8
1946	Experiment station annual variety test series	Mid-season	257	771	114	.947 ± .005	90	± 5.0
1946	Selected cotton improvement groups	Mid-season	78	234	110	.954 ± .006	91	± 4.4
1947	Experiment station annual variety test series	Mid-season	117	351	115	.965 ± .004	93	± 4.4
1947	Selected cotton improvement groups	Early and mid-season	166	498	110	.955 ± .004	91	± 4.5
1948	Selected cotton improvement groups	Early, mid-season, and late	277	1,108	112	.945 ± .003	89	± 5.2
1949	Selected cotton improvement groups	Early, mid-season, and late	260	1,040	113	.942 ± .003	89	± 5.5
1950	Selected cotton improvement groups	Early, mid-season, and late	305	1,119	106	.904 ± .005	82	± 6.9
1951	Selected cotton improvement groups	Early, mid-season, and late	319	638	114	.868 ± .010	75	± 8.0
1952	Selected cotton improvement groups	Early, mid-season, and late	309	618	111	.909 ± .007	83	± 6.6

1/ The 6 cotton-quality elements used as independent variables in each of these correlation analyses were as follows: Grade index, upper half mean length, length uniformity ratio, fiber fineness (weight per inch), fiber strength, and percentage of mature fibers (standard method). Fiber fineness was evaluated by the array method for the 3 crop years of 1945-47 and by the Micronaire method for the 5 crop years of 1948-52.

2/ Each cotton was spun into 2, 3, or 4 yarn sizes.

3/ Absolute value of standard error of estimate ($\bar{S}$) divided by the respective mean value of the dependent variable, multiplied by 100.

Table 3.--Comparison of relative importance of 6 elements of raw-cotton quality to skein strength of 22s carded yarn, processed on long-draft equipment and possessing a semihard twist, as evaluated by multiple correlation analyses, for 10 series of cottons and 8 crop years, 1945-52

Crop year	Groups of cotton according to--	Time of picking	Lots of-- Cotton	Yarn	Factors of cotton quality	Relative importance by-- Rank	Beta coefficient 1/
			Number	Number			
1945	Experiment station annual variety test series	Mid-season	210	210	Fiber strength	1	+0.519 ± 0.033
					Fiber weight per inch	2	- .416 ± .050
					Upper half mean length	3	+ .386 ± .049
					Grade index	4	+ .149 ± .038
					Length uniformity ratio	5	+ .134 ± .036
					Percentage of mature fibers	6	+ .094* ± .038
1946	Experiment station annual variety test series	Mid-season	257	257	Fiber strength	1	+ .470 ± .023
					Upper half mean length	2	+ .423 ± .037
					Fiber weight per inch	3	- .402 ± .048
					Length uniformity ratio	4	+ .162 ± .027
					Grade index	5	+ .035* ± .024
					Percentage of mature fibers	6	+ .033* ± .032
1946	Selected cotton improvement groups	Mid-season	78	78	Upper half mean length	1	+ .584 ± .105
					Fiber weight per inch	2	- .473 ± .116
					Fiber strength	3	+ .391 ± .060
					Percentage of mature fibers	4	+ .120* ± .076
					Length uniformity ratio	5	- .035* ± .060
					Grade index	6	+ .008* ± .061
1947	Experiment station annual variety test series	Mid-season	117	117	Fiber strength	1	+ .479 ± .031
					Upper half mean length	2	+ .429 ± .039
					Fiber weight per inch	3	- .402 ± .046
					Length uniformity ratio	4	+ .162 ± .031
					Grade index	5	+ .100 ± .031
					Percentage of mature fibers	6	+ .067* ± .031
1947	Selected cotton improvement groups	Early and mid-season	166	166	Upper half mean length	1	+ .674 ± .052
					Fiber strength	2	+ .346 ± .036
					Fiber weight per inch	3	- .276 ± .070
					Grade index	4	+ .085* ± .036
					Percentage of mature fibers	5	- .025* ± .049
					Length uniformity ratio	6	+ .066* ± .039
1948	Selected cotton improvement groups	Early, mid-season, and late	277	277	Upper half mean length	1	+ .693 ± .035
					Fiber strength	2	+ .470 ± .031
					Fiber weight per inch	3	- .280 ± .046
					Grade index	4	+ .158 ± .031
					Length uniformity ratio	5	+ .105 ± .032
					Percentage of mature fibers	6	- .019* ± .042
1949	Selected cotton improvement groups	Early, mid-season, and late	260	260	Fiber strength	1	+ .451 ± .034
					Upper half mean length	2	+ .395 ± .036
					Grade index	3	+ .198 ± .035
					Fiber weight per inch	4	- .195 ± .045
					Length uniformity ratio	5	+ .064* ± .036
					Percentage of mature fibers	6	+ .022* ± .037
1950	Selected cotton improvement groups	Early, mid-season, and late	305	305	Fiber strength	1	+ .458 ± .031
					Fiber weight per inch	2	- .374 ± .043
					Upper half mean length	3	+ .358 ± .032
					Length uniformity ratio	4	+ .224 ± .030
					Grade index	5	+ .131 ± .032
					Percentage of mature fibers	6	+ .122* ± .044
1951	Selected cotton improvement groups	Early, mid-season, and late	319	319	Upper half mean length	1	+ .663 ± .038
					Grade index	2	+ .278 ± .037
					Fiber strength	3	+ .122 ± .037
					Fiber weight per inch	4	- .111* ± .058
					Length uniformity ratio	5	+ .059* ± .034
					Percentage of mature fibers	6	+ .046* ± .055
1952	Selected cotton improvement groups	Early mid-season, and late	309	309	Upper half mean length	1	+ .700 ± .031
					Fiber strength	2	+ .267 ± .032
					Percentage of mature fibers	3	- .209 ± .049
					Grade index	4	+ .172 ± .034
					Length uniformity ratio	5	+ .126 ± .032
					Fiber weight per inch	6	+ .048* ± .049

1/ The sign indicates the direction of the contribution of the independent variable to the dependent variable.

* Statistically insignificant, being less than 3 times its standard error.

Table 4.—Comparison of relative importance of 6 elements of raw-cotton quality and yarn size to count-strength product of various sizes of carded yarn, processed on long-draft equipment and possessing a semihard twist, as evaluated by multiple correlation analyses, for 10 series of cottons and 8 crop years, 1945-52

Crop year	Groups of cotton according to—	Time of picking	Lots of— Cotton	Yarn	Factors of cotton quality	Relative importance by— Rank	Beta coefficients 1/
			Number	Number			
1945	Experiment station annual variety test series	Mid-season	210	630	Yarn size	1	-0.671 ± 0.014
					Fiber strength	2	+ .397 ± .015
					Upper half mean length	3	+ .338 ± .022
					Fiber weight per inch	4	- .317 ± .022
					Length uniformity ratio	5	+ .098 ± .016
					Grade index	6	+ .095 ± .016
					Percentage of mature fibers	7	+ .057 ± .017
1946	Experiment station annual variety test series	Mid-season	257	771	Yarn size	1	- .586 ± .012
					Fiber strength	2	+ .413 ± .013
					Upper half mean length	3	+ .399 ± .020
					Fiber weight per inch	4	- .365 ± .027
					Length uniformity ratio	5	+ .130 ± .015
					Grade index	6	+ .029* ± .013
					Percentage of mature fibers	7	+ .016* ± .018
1946	Selected cotton improvement groups	Mid-season	78	234	Yarn size	1	- .815 ± .020
					Fiber weight per inch	2	- .385 ± .041
					Upper half mean length	3	+ .332 ± .037
					Fiber strength	4	+ .241 ± .021
					Percentage of mature fibers	5	+ .102 ± .027
					Grade index	6	+ .022* ± .022
					Length uniformity ratio	7	- .019* ± .021
1947	Experiment station annual variety test series	Mid-season	117	351	Yarn size	1	- .587 ± .015
					Fiber weight per inch	2	- .417 ± .025
					Fiber strength	3	+ .393 ± .017
					Upper half mean length	4	+ .390 ± .021
					Length uniformity ratio	5	+ .142 ± .018
					Grade index	6	+ .107 ± .017
					Percentage of mature fibers	7	+ .069 ± .017
1947	Selected cotton improvement groups	Early and mid-season	166	498	Yarn size	1	- .808 ± .013
					Upper half mean length	2	+ .406 ± .020
					Fiber weight per inch	3	- .272 ± .027
					Fiber strength	4	+ .202 ± .014
					Grade index	5	+ .056 ± .014
					Length uniformity ratio	6	+ .014* ± .015
					Percentage of mature fibers	7	+ .013* ± .019
1948	Selected cotton improvement groups	Early, mid-season, and late	277	1,108	Yarn size	1	- .783 ± .010
					Upper half mean length	2	+ .472 ± .012
					Fiber strength	3	+ .239 ± .011
					Fiber weight per inch	4	- .196 ± .016
					Grade index	5	+ .089 ± .011
					Length uniformity ratio	6	+ .083 ± .011
					Percentage of mature fibers	7	+ .002* ± .014
1949	Selected cotton improvement groups	Early, mid-season, and late	260	1,040	Yarn size	1	- .704 ± .010
					Upper half mean length	2	+ .428 ± .013
					Fiber strength	3	+ .320 ± .012
					Fiber weight per inch	4	+ .200 ± .016
					Percentage of mature fibers	5	- .136 ± .013
					Grade index	6	+ .106 ± .013
					Length uniformity ratio	7	- .069 ± .013
1950	Selected cotton improvement groups	Early, mid-season, and late	305	1,119	Yarn size	1	- .634 ± .013
					Fiber strength	2	+ .389 ± .014
					Fiber weight per inch	3	- .326 ± .020
					Upper half mean length	4	+ .314 ± .014
					Length uniformity ratio	5	+ .200 ± .014
					Percentage of mature fibers	6	+ .120 ± .020
					Grade index	7	+ .105 ± .015
1951	Selected cotton improvement groups	Early, mid-season, and late	319	638	Yarn size	1	- .718 ± .021
					Upper half mean length	2	+ .586 ± .023
					Grade index	3	+ .233 ± .022
					Fiber weight per inch	4	- .106 ± .034
					Fiber strength	5	+ .104 ± .022
					Percentage of mature fibers	6	+ .050* ± .032
					Length uniformity ratio	7	+ .047* ± .020
1952	Selected cotton improvement groups	Early, mid-season, and late	309	618	Yarn size	1	- .765 ± .018
					Upper half mean length	2	+ .564 ± .018
					Fiber strength	3	+ .196 ± .018
					Percentage of mature fibers	4	- .153 ± .027
					Grade index	5	+ .138 ± .019
					Length uniformity ratio	6	+ .093 ± .018
					Fiber weight per inch	7	+ .026* ± .027

1/ The sign indicates the direction of the contribution of the independent variable to the dependent variable.

* Statistically insignificant, being less than 3 times its standard error.

Table 5.--Comparison of ranks of relative importance of 6 elements of raw-cotton quality to skein strength of 22s carded yarn, as based on beta coefficients obtained from multiple correlation analyses, for 10 series of cottons and 8 crop years, 1945-52

Factors of cotton quality--	Rank of importance in--										Frequency of ranks--					
	Exp. sta. ann. var. series			Selected cotton improvement groups							1st.	2d.	3d.	4th.	5th.	6th.
	1945	1946	1947	1946	1947	1948	1949	1950	1951	1952						
Fiber strength	1	1	1	3	2	2	1	1	3	2	5	3	2	-	-	-
Fiber weight per inch	2	3	3	2	3	3	4	2	4*	6*	-	3	4	2	-	1
Upper half mean length	3	2	2	1	1	1	2	3	1	1	5	3	2	-	-	-
Grade index	4	5*	5	6*	4*	4	3	5	2	4	-	1	1	4	3	1
Length uniformity ratio	5	4	4	5*	6*	5	5*	4	5*	5	-	-	-	3	6	1
Percentage of mature fibers	6*	6*	6*	4*	5*	6*	6*	6*	6*	3	-	-	1	1	1	7

* Value of beta coefficient was statistically insignificant, being less than 3 times its standard error.

Table 6.--Comparison of ranks of relative importance of 6 elements of raw-cotton quality and yarn size to count-strength product of various sizes of carded yarn, as based on beta coefficients obtained from multiple correlation analyses, for 10 series of cottons and 8 crop years, 1945-52

Factors of cotton quality and yarn size--	Rank of importance in--										Frequency of ranks--						
	Exp. sta. ann. var. series			Selected cotton improvement groups													
	1945	1946	1947	1946	1947	1948	1949	1950	1951	1952	1st.	2d.	3d.	4th.	5th.	6th.	7th.
Yarn size	1	1	1	1	1	1	1	1	1	1	10	-	-	-	-	-	-
Fiber strength	2	2	3	4	4	3	3	2	5	3	-	3	4	2	1	-	-
Upper half mean length	3	3	4	3	2	2	2	4	2	2	-	5	3	2	-	-	-
Fiber weight per inch	4	4	2	2	3	4	4	3	4	7*	-	2	2	5	-	-	1
Length uniformity ratio	5	5	5	7*	6*	6	7	5	7*	6	-	-	-	-	4	3	3
Grade index	6	6*	6	6*	5	5	6	7	3	5	-	-	1	-	3	5	1
Percentage of mature fibers	7	7*	7	5	7*	7*	5	6	6*	4	-	-	-	1	2	2	5

* Value of beta coefficient was statistically insignificant, being less than 3 times its standard error.

Table 7.--Comparison of signs before beta coefficients for 6 elements of raw-cotton quality in relation to skein strength of 22s carded yarn, as obtained from multiple correlation analyses, for 10 series of cottons and 8 crop years, 1945-52

Factors of cotton quality--	Sign before beta coefficients in--										Summation of signs--	
	Exp. sta. annual variety series			Selected cotton improvement groups							Plus	Minus
	1945	1946	1947	1946	1947	1948	1949	1950	1951	1952		
Fiber strength	+	+	+	+	+	+	+	+	+	+	10	0
Fiber weight per inch	-	-	-	-	-	-	-	-	-*	+*	1	9
Upper half mean length	+	+	+	+	+	+	+	+	+	+	10	0
Grade index	+	+*	+	+*	+*	+	+	+	+	+	10	0
Length uniformity ratio	+	+	+	-*	+*	+	+*	+	+*	+	9	1
Percentage of mature fibers	+*	+*	+*	+*	-*	-*	+*	+*	+*	-	7	3

* Value of beta coefficient was statistically insignificant, being less than 3 times its standard error.

Table 8.--Comparison of signs before beta coefficients for 6 elements of raw-cotton quality and yarn size in relation to count-strength product of carded yarn, as obtained from multiple correlation analyses, for 10 series of cottons and 8 crop years, 1945-52

Factors of cotton quality and yarn size--	Sign before beta coefficients in--										Summation of signs--	
	Exp. sta. annual variety series			Selected cotton improvement groups								
	1945	1946	1947	1946	1947	1948	1949	1950	1951	1952	Plus	Minus
Yarn size	-	-	-	-	-	-	-	-	-	-	0	10
Fiber strength	+	+	+	+	+	+	+	+	+	+	10	0
Upper half mean length	+	+	+	+	+	+	+	+	+	+	10	0
Fiber weight per inch	-	-	-	-	-	-	+	-	-	+*	2	8
Length uniformity ratio	+	+	+	-*	+*	+	-	+	+*	+	8	2
Grade index	+	+*	+	+*	+	+	+	+	+	+	10	0
Percentage of mature fibers	+	+*	+	+	+*	+*	-	+	+*	-	8	2

* Value for beta coefficient was statistically insignificant, being less than 3 times its standard error.

Table 9.--Comparison of regression equations showing the relation between the respective dependent variables and the collective independent variables, as developed from multiple linear correlation analyses of data representing various series of cottons and 8 crop years, 1945-52 1/

Equation identification--					Regression equation involving--										
							Coefficients for independent variables of--							Standard error of estimate ($\bar{S}$)	
Number	Yarn size	Factors included	Observations on which based	Crop year	Estimated yarn-strength	(A) Constant	(X_{88}) Grade of cotton, index	(X_{17}) Upper half mean length, in inches	(X_{19}) Length uniformity ratio, index	(X_4) or (X_{104}) Fiber fineness, micrograms per inch	(X_{33}) Fiber strength, 1,000 lb. per sq. in.	(X_{35}) Percentage of mature fibers	(X_{41}) Yarn size	Absolute	Relative
	Number	Number	Number		Lb. per skein									2/	Percent 3/
(1)	14s	6	277	1948	X'_{96} =	- 120.53	+ 0.457	+ 146.561	+ 0.898	- 7.283	+ 0.916	- 0.030	--	± 7.48	±3.97
(2)	14s	6	260	1949	X'_{96} =	- 242.68	+ .954	+ 142.278	+ .848	- 6.001	+ 1.562	+ .295	--	± 10.73	±5.63
(3)	14s	6	305	1950	X'_{96} =	- 344.93	+ .612	+ 125.129	+ 2.793	- 16.147	+ 1.800	+ .526	--	± 11.94	±6.74
(4)	22s	6	828	1945-47	X'_{3} =	- 55.34	+ .054	+ 61.425	+ .682	- 10.444	+ .965	+ .211	--	± 5.60	±5.00
(5)	22s	6	277	1948	X'_{8} =	- 82.16	+ .288	+ 93.473	+ .449	- 5.778	+ .753	- .042	--	± 4.87	±4.36
(6)	22s	6	260	1949	X'_{8} =	- 125.31	+ .564	+ 81.498	+ .335	- 4.862	+ 1.070	+ .070	--	± 5.96	±5.26
(7)	22s	6	305	1950	X'_{8} =	- 213.03	+ .385	+ 80.861	+ 1.652	- 9.976	+ 1.125	+ .287	--	± 7.11	±6.70
(8)	22s	6	319	1951	X'_{3} =	- 166.11	+ .714	+ 125.760	+ .733	- 3.533	+ .285	+ .150	--	± 8.73	±7.63
(9)	22s	6	309	1952	X'_{8} =	- 189.05	+ .519	+ 125.031	+ 1.338	+ 1.487	+ .622	- .578	--	± 6.98	±6.26
(10)	36s	6	277	1948	X'_{13} =	- 66.08	+ .145	+ 69.138	+ .357	- 4.401	+ .383	- .001	--	± 3.38	±5.60
(11)	36s	6	260	1949	X'_{13} =	- 64.12	+ .341	+ 46.588	+ .192	- 3.393	+ .542	- .001	--	± 3.32	±5.39
(12)	36s	6	305	1950	X'_{13} =	- 127.01	+ .212	+ 57.003	+ .808	- 5.962	+ .656	+ .200	--	± 4.09	±7.04
(13)	50s	6	828	1945-47	X'_{15} =	- 28.96	- .005	+ 34.222	+ .305	- 5.557	+ .361	+ .084	--	± 2.37	±5.98
(14)	50s	6	277	1948	X'_{15} =	- 59.36	+ .097	+ 56.139	+ .334	- 4.095	+ .237	+ .051	--	± 2.41	±5.93
(15)	50s	6	260	1949	X'_{15} =	- 55.97	+ .199	+ 40.887	+ .154	- 2.901	+ .361	+ .050	--	± 2.42	±6.17
(16)	50s	6	305	1950	X'_{15} =	- 100.46	+ .139	+ 43.519	+ .645	- 5.099	+ .444	+ .182	--	± 3.10	±8.47
(17)	Any	7	2,484	1945-47	X'_{91} 4/ =	- 601.01	+ .618	+1,378.292	+14.833	-247.840	+19.852	+ 4.624	-17.969	±126.44	±5.75
(18)	Any	7	1,108	1948	X'_{91} 4/ =	-1,625.09	+ 5.821	+2,291.254	+12.747	-145.411	+13.776	+ .164	-17.301	±119.54	±5.23
(19)	Any	7	1,040	1949	X'_{91} 4/ =	-1,273.20	+ 9.129	+2,694.825	-11.703	+151.476	+23.106	-13.133	-19.523	±127.01	±5.48
(20)	Any	7	1,119	1950	X'_{91} 4/ =	-4,106.34	+ 7.263	+1,788.700	+35.733	-214.647	+23.168	+ 6.757	-16.870	±151.00	±6.93
(21)	Any	7	638	1951	X'_{91} 4/ =	-3,119.48	+15.042	+2,793.311	+14.684	- 85.275	+ 6.108	+ 4.068	-18.331	±183.20	±7.97
(22)	Any	7	618	1952	X'_{91} 4/ =	-3,342.24	+11.081	+2,678.113	+26.337	+ 21.684	+12.153	-11.230	-18.670	±146.68	±6.60

1/ The regression equations listed represent carded cotton yarns of a warp-type construction, processed on long-draft equipment, and possessing a semi-hard twist.

2/ For strength of 14s, 22s, 36s, and 50s yarn, estimated by use of individual yarn-size equations (1) through (16), the standard error of estimate ($\bar{S}$) is expressed in pounds per skein; for count-strength product of any yarn size, estimated by use of equations (17) through (22), the standard error of estimate ($\bar{S}$) is defined in count-strength-product units.

3/ Absolute value of standard error of estimate ($\bar{S}$) divided by the respective mean value of the dependent variable, multiplied by 100.

4/ Estimated yarn strength obtained by use of equation is in terms of count-strength product units which may be converted into pounds per skein by dividing that answer by the yarn size substituted in the equation.